

# CLEAN ENERGY SYSTEMS

Carbon-Negative Energy  
Introduction & Deployment  
October 2018

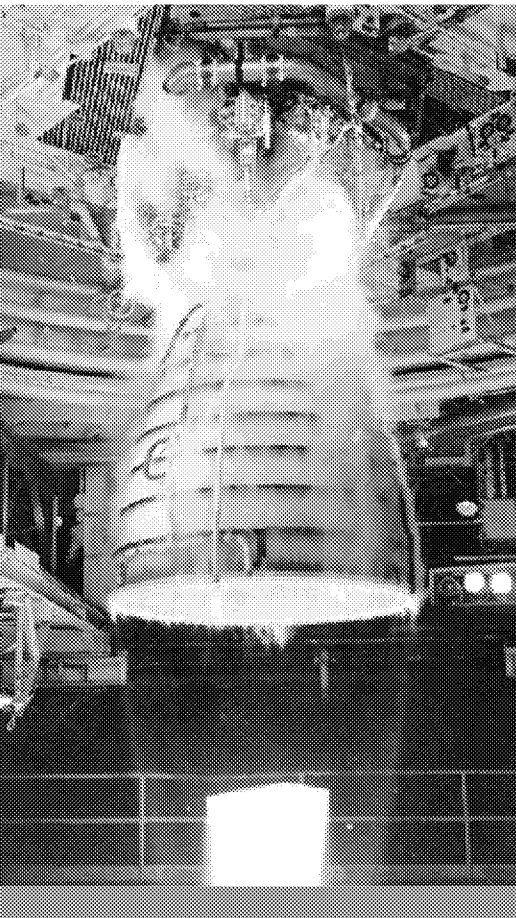
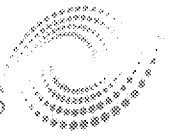
# .... AGENDA

- Introduction to Clean Energy Systems
- Carbon-Negative Energy
  - What it is and Why we need it
  - How it works
  - Potential projects
- Summary & Next Steps

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# CES | COMPANY BACKGROUND & OVERVIEW

CLEAN ENERGY SYSTEMS



- Founded in 1993 by former Aerojet (a GenCorp company) aerospace engineers; incorporated in 1996, Clean Energy Systems, Inc. (CES)
- Multiple locations in California:
  - Corporate Engineering and Headquarters, Rancho Cordova (Sacramento Area)
  - Kimberlina Test Facility (former 5 MWe Biomass Power Plant), Bakersfield
  - Placerita Power Plant (former 120 MWe CHP Plant), Santa Clarita
- 30 patents issued on zero-emissions oxy-combustion technology power cycles (36 pending)
- Focused on developing and deploying enabling technologies for advanced clean energy
  - Oxy-Fuel (O-F) Pressurized Direct and Indirect Steam Gas Generators and Reheat Combustors
  - Compact Diffusion Bonded Heat Exchangers
  - O-F Turbines (OFTs) with development partners

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# .... OUR VISION



Clean Energy Systems is the global leader in the development and deployment of carbon reducing energy systems

The Power to Reverse Climate Change



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## Carbon Negative Energy (CNE)

**Removes existing carbon (CO<sub>2</sub>)** from the atmosphere and produces power

**CES seeks to build** a portfolio of carbon negative energy (CNE) plants in California

**California offers** a unique combination of opportunities to deploy CNE

- 1 Enormous potential for onshore carbon storage
- 2 Excess of biomass wastes and idled resources
- 3 Robust carbon pricing and trading network
- 4 Strong government support and commitment to low carbon future
- 5 Process produces valuable water in drought prone agricultural zone

## Carbon Reduction Solutions (CRS)

**Reduces the amount of carbon** released to the atmosphere from existing industrial processes

This is accomplished by:

**Clean steam generation**

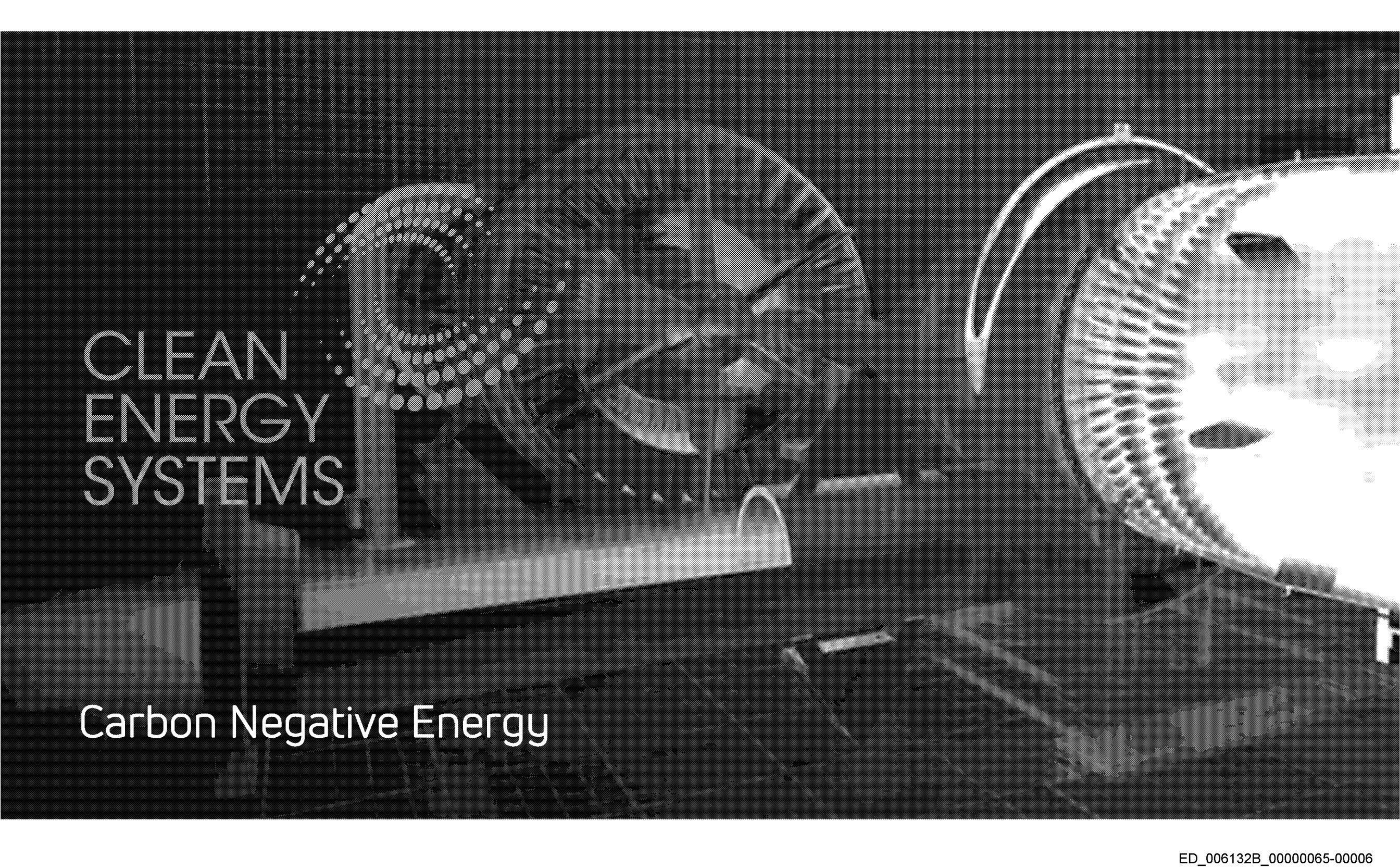
**Heat exchange solutions** to enable efficient renewable energy and clean power production

**Zero-emissions power production**

**Energy storage solutions**

In addition, CES offers engineering services and legacy aerospace work to drive technology advancements that can be incorporated into its products





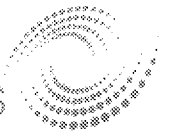
# CLEAN ENERGY SYSTEMS

Carbon Negative Energy

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# CARBON NEGATIVE ENERGY I WHAT IS BIOCCS?

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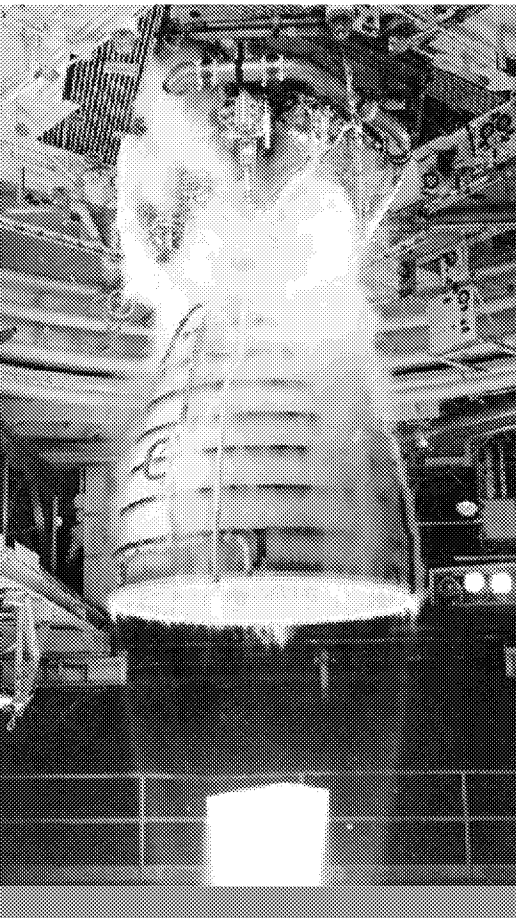
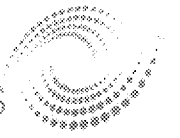
- Carbon removal refers to any process or system capable of removing and sequestering carbon from the air over its life cycle
  - Enables clean up of emissions that have accumulated in the atmosphere
- BioCCS refers to any bioenergy process that captures and permanently stores carbon safely underground through carbon capture and storage (CCS)
  - Also known as BECCS (bioenergy with carbon capture and storage)
- There is a need for cost effective, scalable technologies that can be readily deployed in order to meet global climate goals
  - BioCCS systems hold vast potential to remove the harmful greenhouse gas carbon dioxide (CO<sub>2</sub>) from the atmosphere while producing electricity and/or clean fuels

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# REVERSING CLIMATE CHANGE

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- At the UN Climate Change Conference in Paris, the world set ambitious goals to limit global temperature rise to less than 2 deg. C to help stave off the detrimental effects of global climate change
- Societies across the globe are implementing strict, long-term policies to reduce greenhouse gas emissions including carbon taxes
- However, according to the IPCC, we will fail to meet this target as greater than 100% emissions reduction is required
- In order to cease current global climate trends, we not only need to reduce carbon emissions, but **reverse** them
  - *The only solution is carbon-negative plants deployed on a grand scale*
  - *However there are no carbon negative energy plants operational today*

CES technology is available today, based on 25 years of work and an investment in excess of \$125 million

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# CNE | WHY NOW?

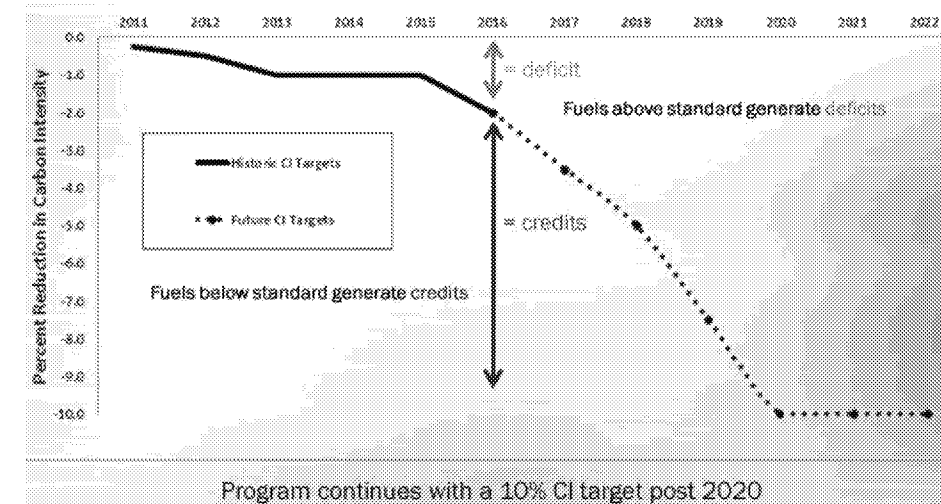


## Multiple factors aligned to make deployment profitable

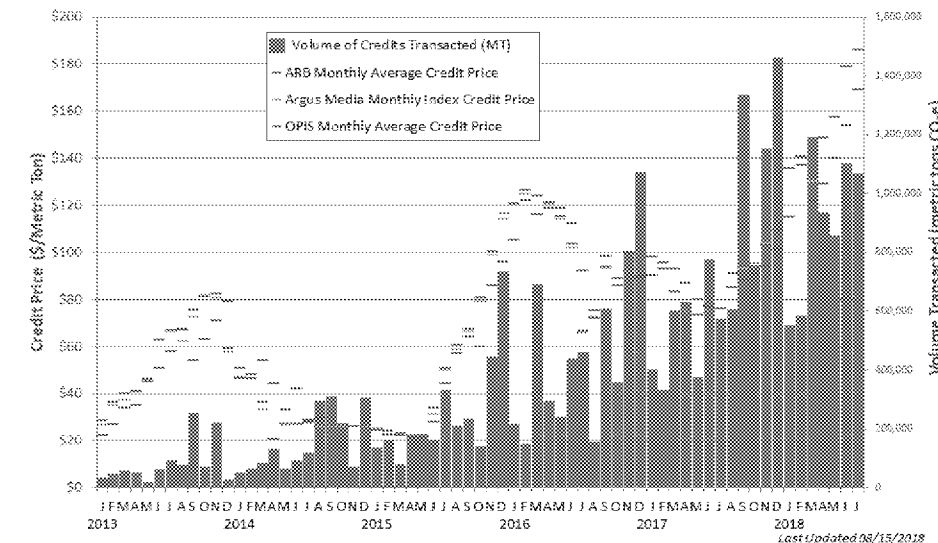
- Revenues for carbon capture have gone from \$20/ton to \$240/ton for select applications (CNE)
  - Federal Tax Credit increased from \$20/ton to \$50/ton in Feb-2018
  - California's LCFS credits in the transportation sector are "biting" with extension of program through 2030 and resolution of litigation – projected to hit \$190/ton this year
- At the same time, the Biomass Power industry in California has collapsed due to competition from wind and solar
  - Resulted in stranded assets that can only be used for alternative purposes
  - Feedstock pricing collapsed; long-term contracts now available
- Enormous potential for CCS in California; projects build on knowledge gained from past efforts (e.g. WESTCARB)
- Required CES technology has been built and tested: No Technology Risk

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## California's Declining Carbon Intensity Curve



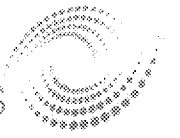
## Monthly LCFS Credit Price and Transaction Volume



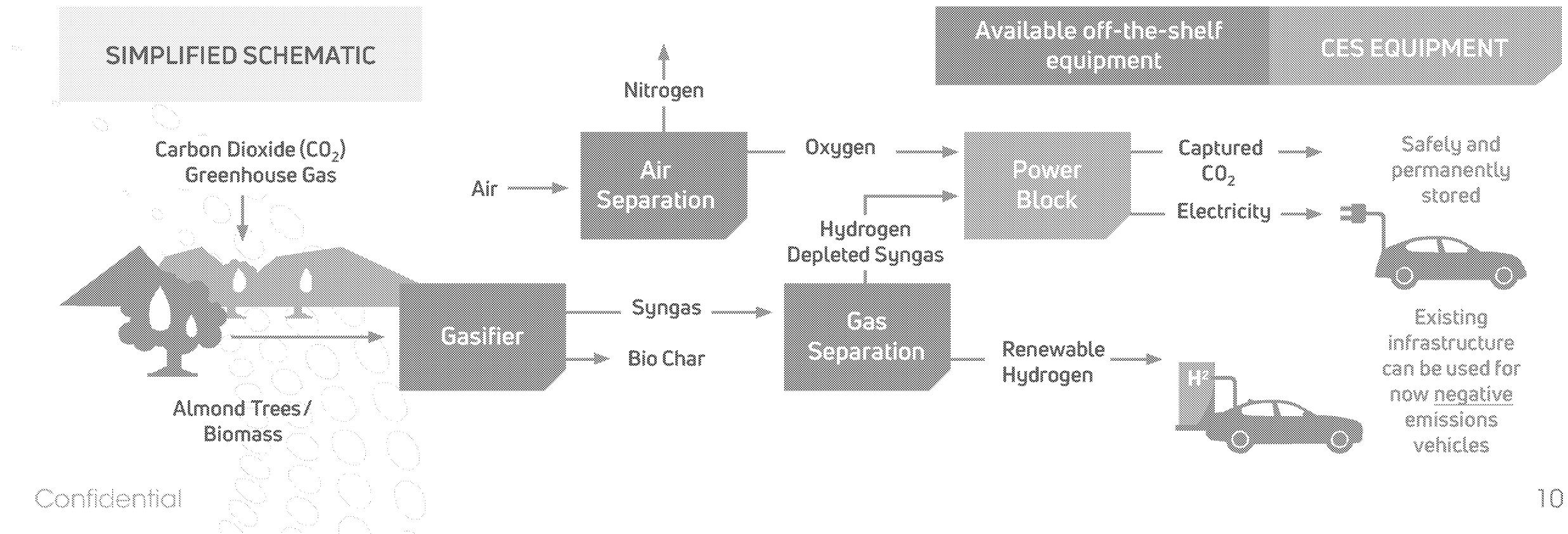
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# CES CNE I HOW IT WORKS

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CNE plants use waste biomass fuels that consume carbon during their lifetime to produce syngas, from which hydrogen is separated for sale to the transportation sector. The remaining (hydrogen-depleted) fuel is passed through CES technology to produce power with full carbon capture, effectively removing CO<sub>2</sub> from the atmosphere

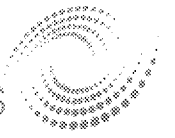


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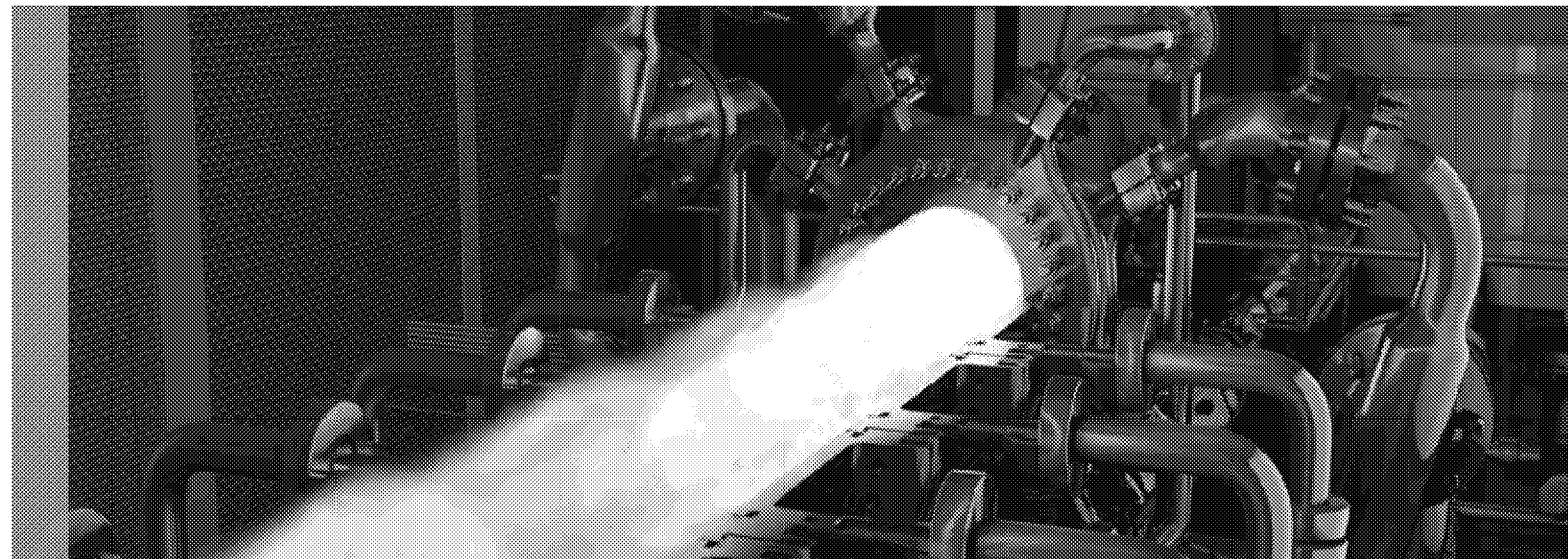
# CES ENABLING TECHNOLOGY I PRESSURIZED OXY-COMBUSTION

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Derived from the American space program, CES combustion systems burn nearly pure oxygen (instead of air) with gaseous fuels (such as natural gas, associated gas, syngas, high-CO<sub>2</sub> content natural gas or liquid fuel) for a cleaner, more efficient combustion process

The intimate mixing of gases via unique IP creates combustion with only water (high pressure steam) and CO<sub>2</sub> as its two products which are easily separated for capture and storage



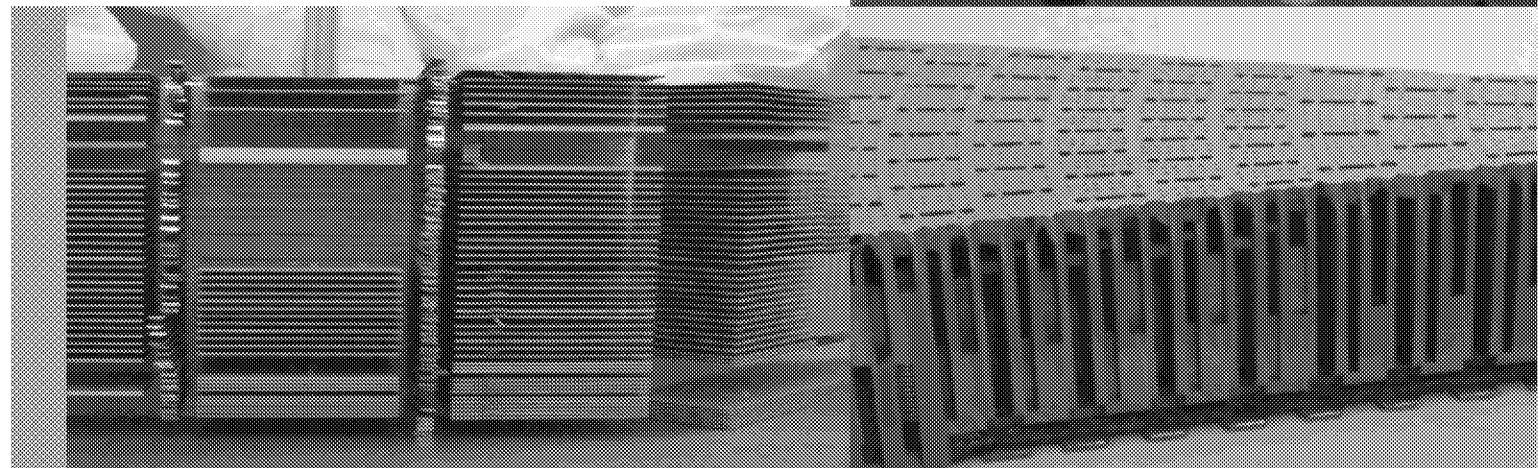
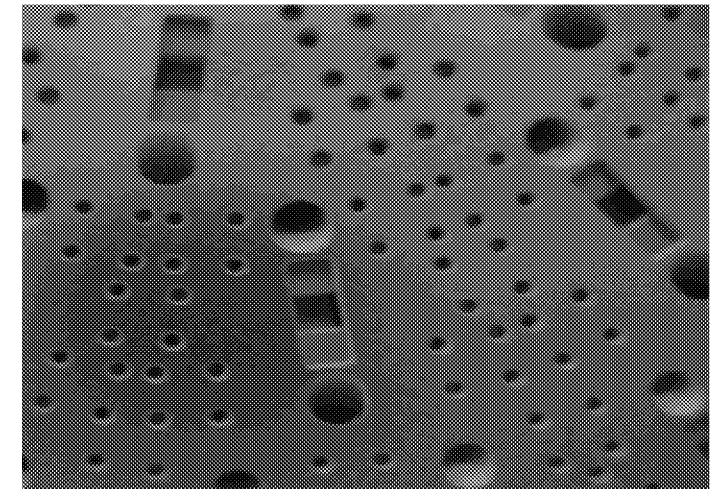
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# CES ENABLING TECHNOLOGY I PLATELETS

- **Precise, stoichiometric combustion** enabled by proven, reliable, platelet injectors
- **Hundreds of individual platelets** are designed and photo-etched to create unique, intricate patterns
- **Platelets are stacked** in a set pattern to form 3D internal flow passages not possible via any other process
- **Platelet stack is then bonded into a single monolithic structure** that can then be machined and assembled
- **The resultant intricate Individual pathways** channel fuel, oxygen, and water to hundreds of combustion elements where intimate, stoichiometric mixing occurs, resulting in complete combustion



# CNE I PROJECT OVERVIEW

Kimberlina Power Plant



## Base Case CNE Plant

- 300 TPD biomass feedstock; Ag waste, forest management, RDF, MSW, etc.
  - 10-15 trucks per day
- Produces approx. 5,400 kg/day renewable hydrogen (RH<sub>2</sub>)
  - Enough to fuel ~ 1,000 FCEVs
- Captures and permanently stores approx. 485 tonne/day of CO<sub>2</sub>
  - Equivalent to removing over 31,500 passenger vehicles from the roads each year
- Electricity produced covers plant loads
- Repeatable and scalable

## CNE Plant Options

- Ability to produce renewable natural gas in place of, or in addition to RH<sub>2</sub>
  - Approx. 3,200 MM BTU/day
  - Reduces the total amount of CO<sub>2</sub> captured and stored
- Same plant can produce up to 6 MWe (net) renewable power
  - Same amount of CO<sub>2</sub> captured and stored but no longer produces other renewable fuels (RH<sub>2</sub>, RNG)

# CNE I PROJECT KPP

## CES' Kimberlina Power Plant

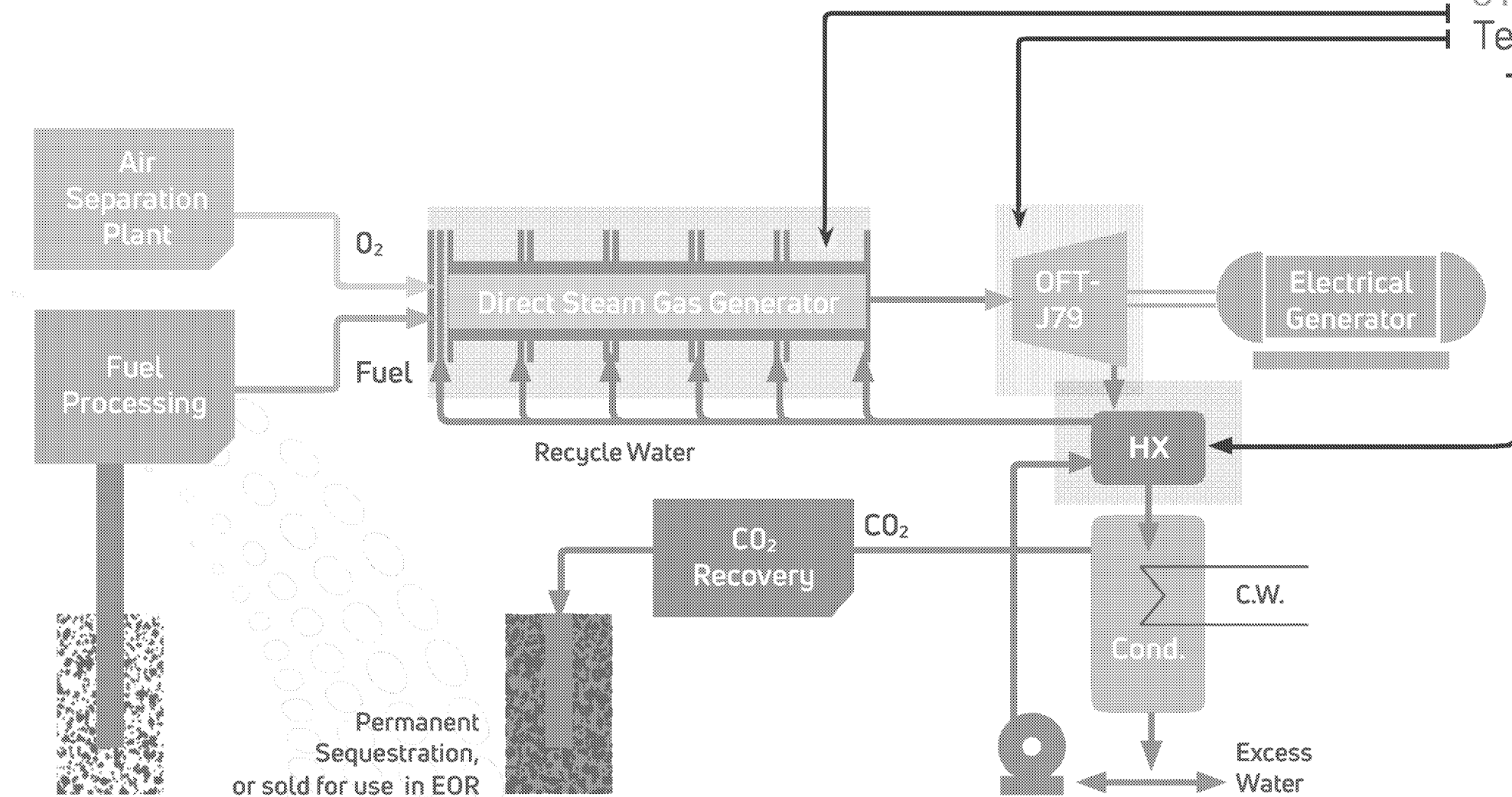
- Located in the heart of the California's Central Valley
  - Surrounded by fruit and nut orchards
  - Sitting on top of a WESTCARB identified CO<sub>2</sub> storage site, &
  - Between heavy and light oil fields in need of steam and CO<sub>2</sub>
- Currently home to CES' commercial and test equipment
  - World's largest pressurized O-F combustion test facility
- 300 TPD biomass plant; requires install of gasifier, ASU and RH<sub>2</sub> liquefaction and transportation system
- CO<sub>2</sub> to be sequestered on-site; backup option to sell to nearby oil producers
- RH<sub>2</sub> to be sold into transportation section, through California refineries to reduce the carbon intensity of existing fuels



CES' J79 Oxy-Fuel Turbine

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# CES | POWER BLOCK



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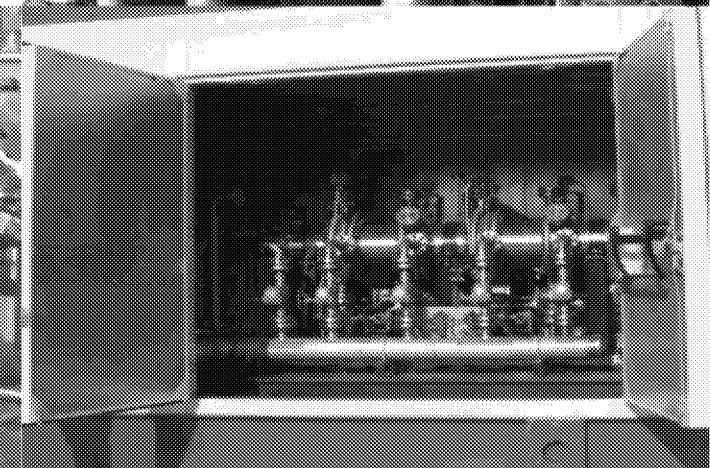
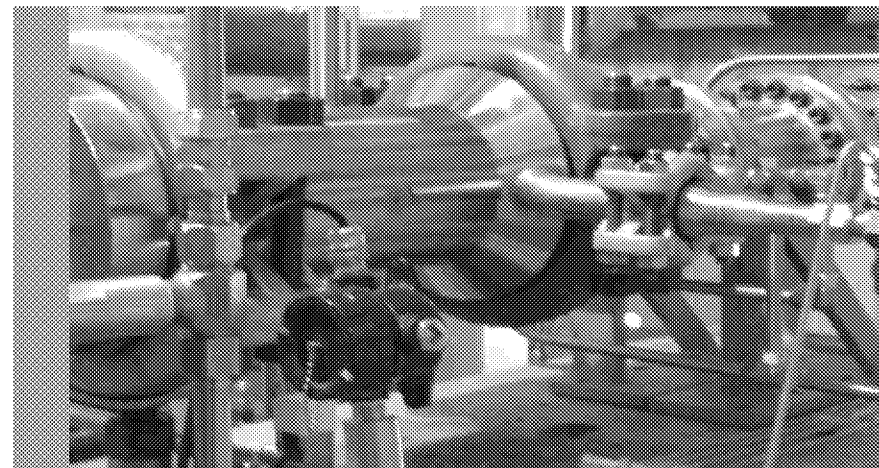
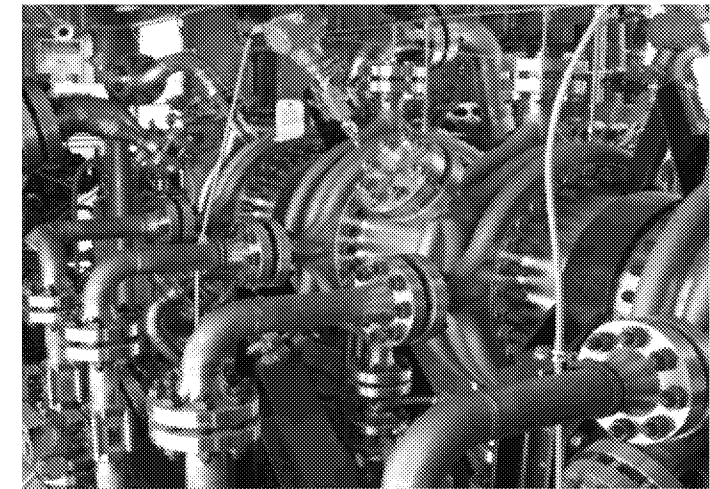
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# CES I DIRECT STEAM GAS GENERATORS

**Compact system produces only steam and high purity CO<sub>2</sub> (when burning a hydrocarbon based fuel), and massive amounts of thermal energy**

- Water injection and jacket cooling incorporated for long life
- Standalone installation-Includes control and monitoring system
- Ramps to full power in seconds

- Current designs with 10 cm (4 inch) or 30 cm (12 inch) internal diameters
- Range from 10 to 200 MWt delivering temperatures up to 1,650 °C (3,000 °F) and capable of pressures over 110 bar (1,600 psi)

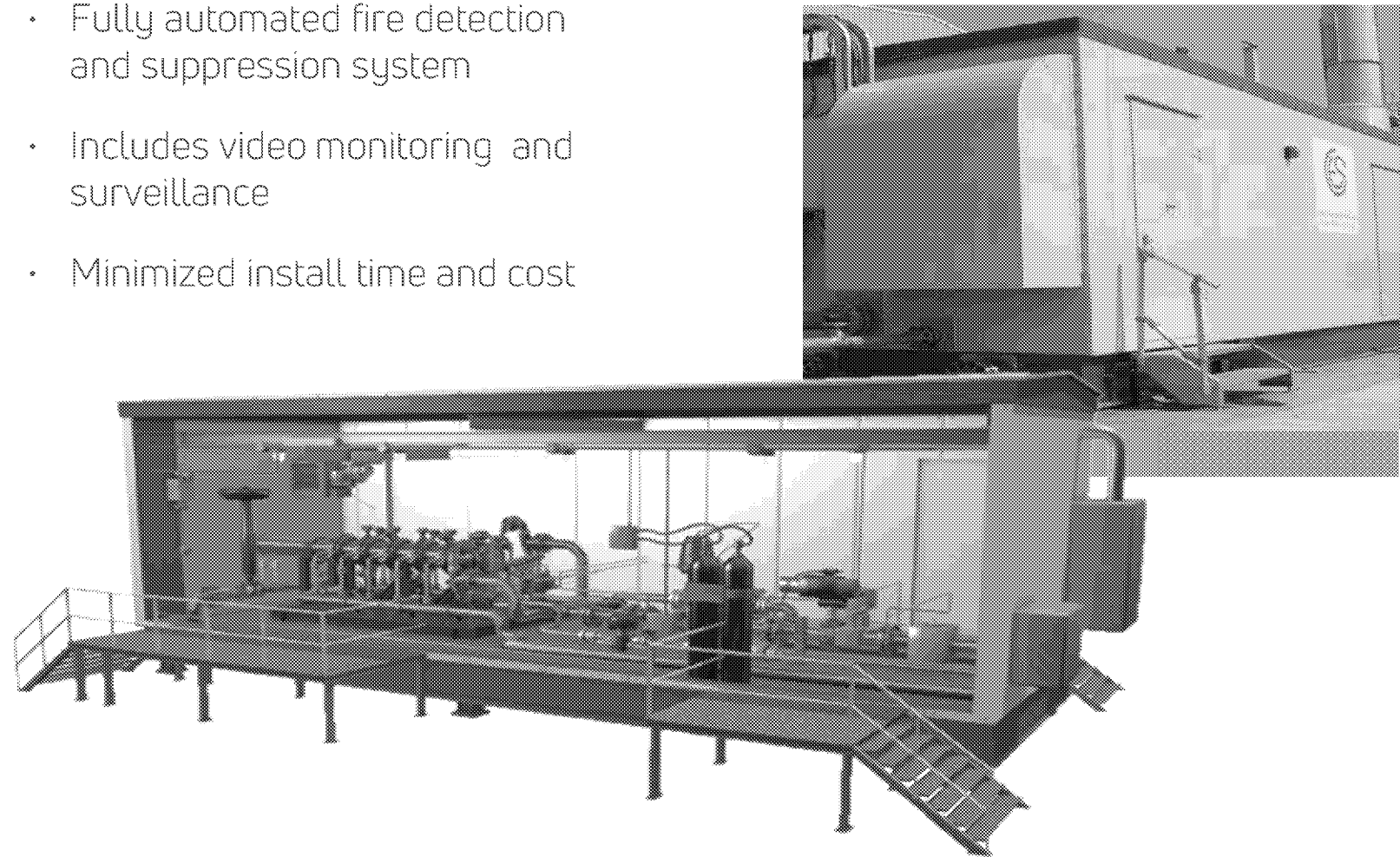


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# CES I DIRECT STEAM GAS GENERATOR PACKAGE

## Fully containerized oxy-combustion system for easy transport and installation

- **Combustor:** 2 meters (6 feet) long with 30 cm (12 inch) internal diameter
- **Container:** 3.3 meters (11 feet) x 3.3 meters (11 feet) x 12 meters (40 feet)
- Fits on standard shipping vehicles
- Designed and built to ASME Section VIII, Division 1
- Fully automated fire detection and suppression system
- Includes video monitoring and surveillance
- Minimized install time and cost



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# CES I OXY-FUEL TURBINES

**With development partners, turbines designed for high-quality steam and high CO<sub>2</sub>-content drive gas**

- Currently two turbines retrofit
- Removed front-end compressor section and replaced with thrust balance system
- Modified for pressurized steam-CO<sub>2</sub> gas
- Operate at gas turbine conditions

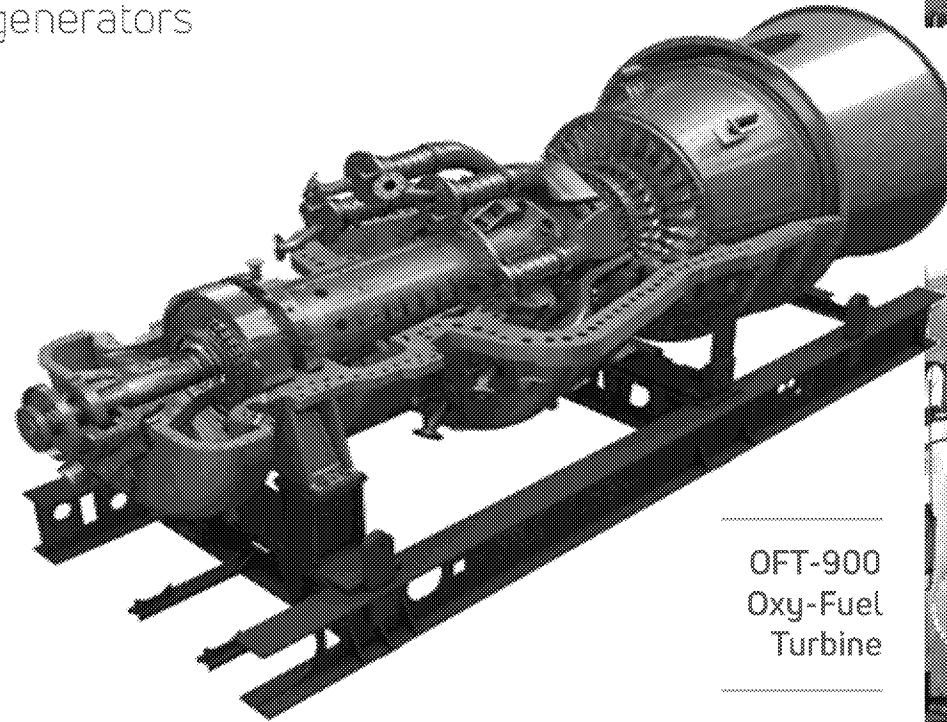
## **GE J79 retrofit to OFT-J79**

- Up to 43 MWe from 12 MWe baseline

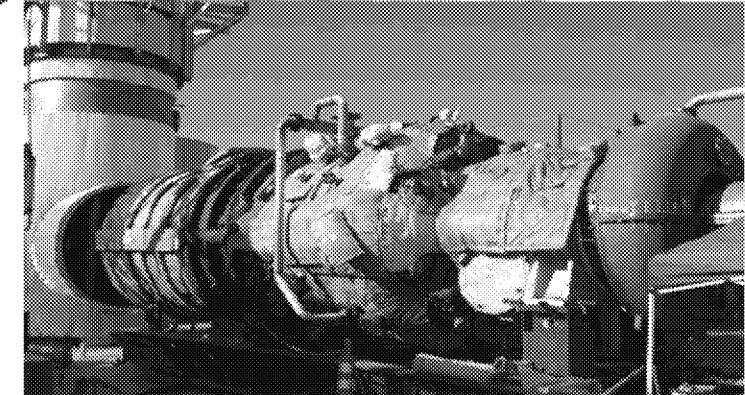
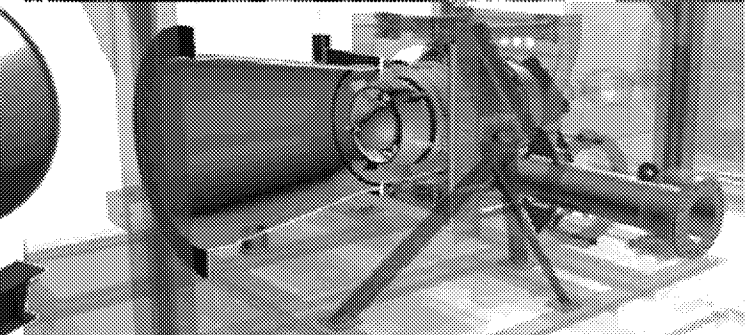
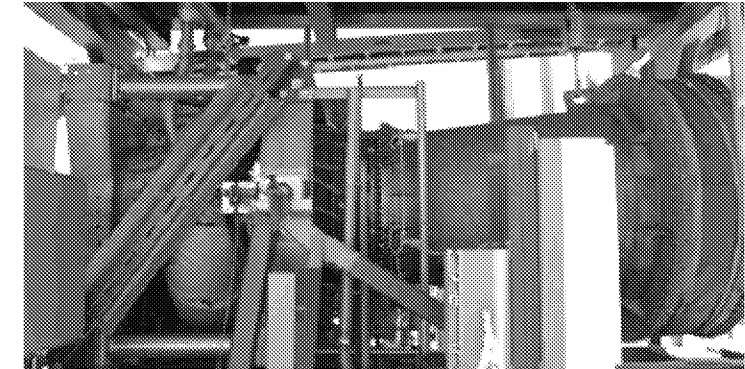
## **SGT-900 (W251 B12) retrofit to OFT-900**

- Up to 150 MWe from 43 MWe baseline
- Makes use of CES reheat combustors
- CES, FTT, and Siemens design

Future turbine potential for new designs matching temperature/pressure profile of CES direct steam gas generators



OFT-J79  
Oxy-Fuel  
Turbine



OFT-900  
Oxy-Fuel  
Turbine

*With development partners*

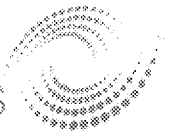
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# CES | COMPACT HEAT EXCHANGERS

HEXCES

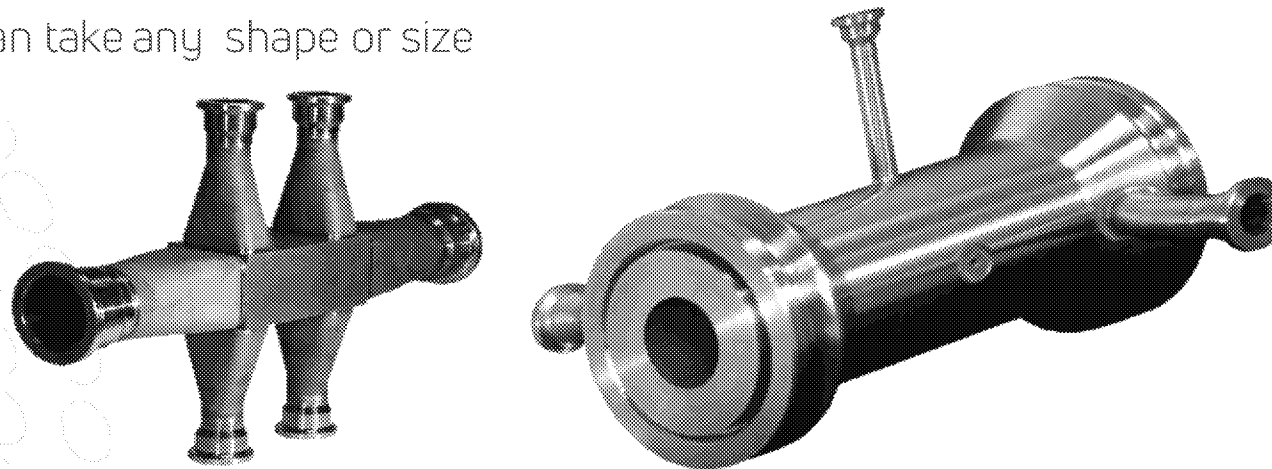
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## COMPACT PLATELET HEAT EXCHANGERS (CPHX)

Diffusion bonded heat exchangers enable thermal energy storage (concentrating solar power) and next generation energy systems

- Capable of handling extreme operating temperatures (-200 to 900 °C) and pressures (600+ bar)
- 4 to 6 times smaller and lighter than conventional exchangers
- Unparalleled thermal effectiveness
- Unique designs can take any shape or size



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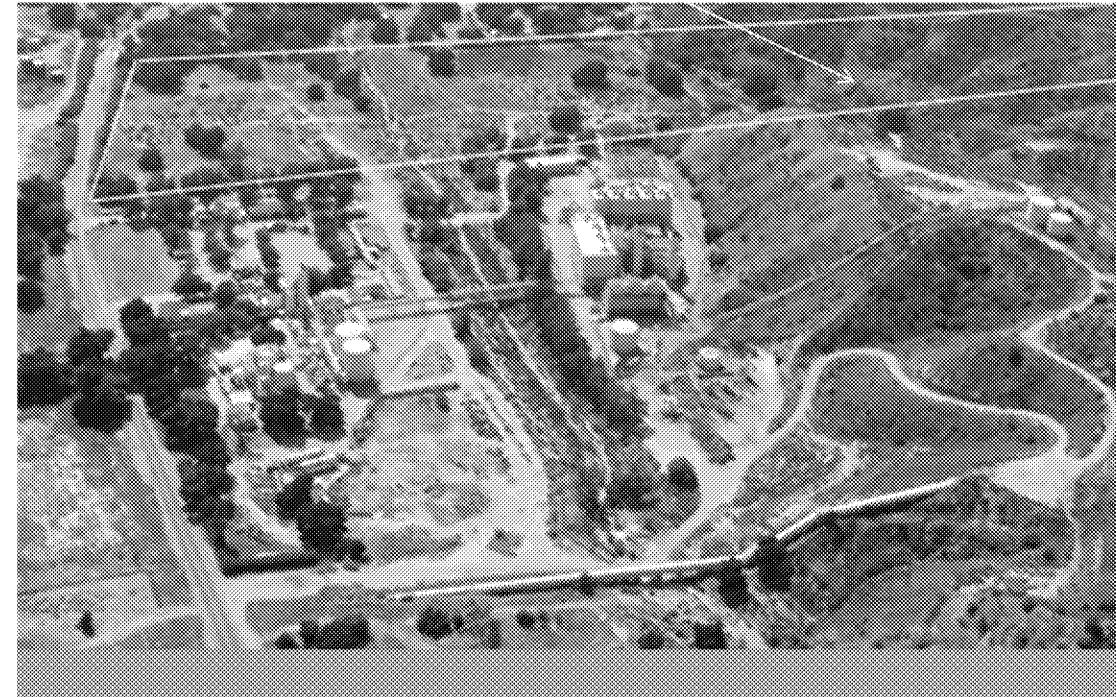
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# CNE I PROJECT PPP

## CES' Placerita Power Plant

- Former 120 MWe combined heat and power plant offers substantial infrastructure, making repower option attractive
- Requires new biomass handling system, gasifier, and CES powerblock
- CO<sub>2</sub> storage not available on-site; would be piped to nearby storage sites (CCS) and/or for use in enhanced oil recovery (EOR)
- May be a better option for RNG production and/or energy storage to serve the LA Basin

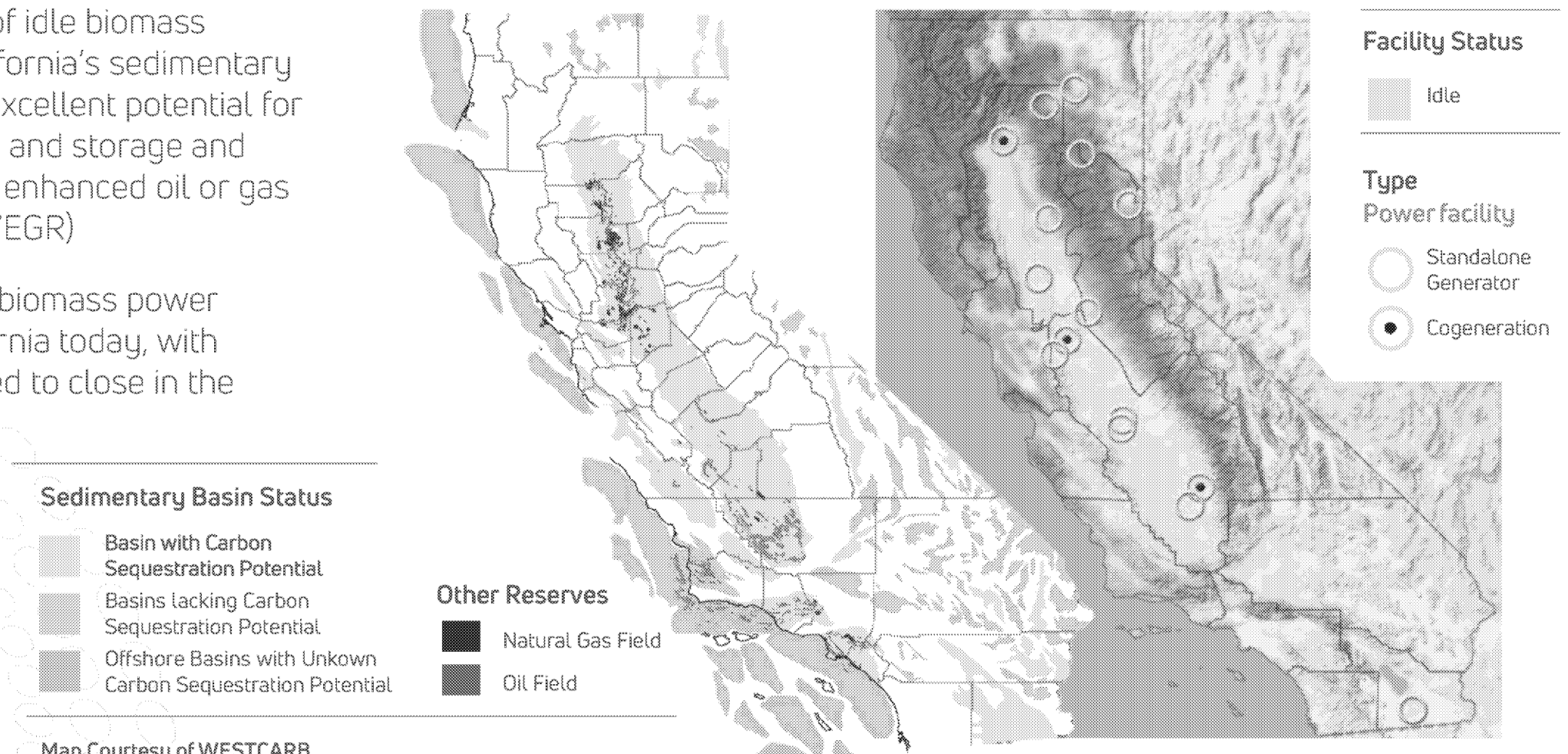
Placerita Power Plant & Adjoining 38 acres



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# CNE I FUTURE POTENTIAL PROJECTS IN CALIFORNIA

- A comparison of idle biomass facilities to California's sedimentary basins shows excellent potential for carbon capture and storage and possible use in enhanced oil or gas recovery (EOR/EGR)
- At least 15 idle biomass power plants in California today, with more anticipated to close in the coming years



Map Courtesy of WESTCARB

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# CNE I SUMMARY & NEXT STEPS

CLEAN ENERGY SYSTEMS



- CES Carbon Negative Energy (CNE) plants have the potential to generate renewable power and/or fuels (RNG, RH<sub>2</sub>) while effectively removing millions of tons of CO<sub>2</sub> from the atmosphere
  - Plants can be scaled and configured to suit specific site needs
- CES plans to develop a portfolio of CNE plants across California making use of currently idled biomass facilities; revitalizing valuable assets and improving the state's air quality
- CES is in the project development stages for a first CNE plant at its Kimberlina facility in Bakersfield, including securing feed and offtake agreements, kicking off permitting activities, etc.
- Continue feasibility study exploring options for Placerita Power Plant
- Identify, locate, and secure additional sites for CNE plants



# Thank You!

For more information contact:

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